[0025] An additional understanding of the selection criteria of the diffusive transport modifier to reduce the ion mobilities within a pore solution is gained by considering electrical conduction. In electrical conduction, the electrophoretic mobility μ_e is the ratio of the ion drift velocity v_d and the applied electric field E ($\mu_e = e\mu$, where e is the charge of an electron). This shows that there may be a fundamental similarity between diffusion coefficients and electrical conductivity, at the molecular scale. Therefore, the relative effect on diffusion may be inferred from the relative effect upon the electrical conductivity. This similarity serves as a basis for estimating diffusion coefficients from electrical migration (applied electric field) tests, such as ASTM C 1202.

[0026] There are many materials in the prior art that are used to change the bulk viscosity of a wet concrete mixture. These materials have been typically used for applying mortar to vertical surfaces and in self-consolidating concretes. These viscosity modifiers, however, are typically composed of large molecules, potentially violating the applicability of the Stokes relation and therefore may not be suitable for extending the service life of the concrete.

[0027] Taken together, these phenomena suggest an inverse proportion of conductivity with viscosity for smaller molecules and the direct proportion of diffusivity with conductivity. This provides a basis for an initial screening in the selection of diffusive transport modifiers. Advantageously, selected diffusive transport modifiers of aspects of the present invention are water soluble organic materials having a molecular weight less than about 1,000 g/mol. More advantageously, selected diffusive transport modifiers of aspects of the present invention are water soluble organic materials which exhibit a reduction in electrical conductivity of a 0.1 mol KCl/kg water solution by about at least 20%. Most advantageously, selected diffusive transport modifiers of aspects of the present invention are water soluble organic materials that achieve an increase in solution viscosity of at least about 1.25× that of distilled water. However, other practical considerations should be considered in methods of making aspects of the modified concrete of the present invention.

[0028] When introducing chemical admixtures into a wet concrete mixture, either a retardation of cement hydration may occur or an exothermic reaction during curing may cause the temperature of the concrete to be excessive, causing cracking. This characteristic of some diffusive transport modifiers may make them inadequate for use in larger masses of concrete typically used in construction, i.e. structural concrete. However, alternative methods for making the diffusive transport modified concrete may be used to curb excessive retardation (or acceleration) of the cement hydration reactions thus enabling the application of such diffusive transport modifiers.

[0029] Another aspect of the present invention comprises a conventional method of making concrete where the aggregate(s), water, cementing agent(s), and diffusive transport modifier(s) are all mixed to form the wet concrete mixture. The diffusive transport modifier(s) may be pre-mixed into the mixing water prior to the mixing of the concrete or added directly to the concrete mixer. However, since concretes absorb external curing solutions during their hydration (due to the chemical shrinkage that accompanies the hydration reactions), an alternative delivery may be used.

[0030] Another aspect of the present invention uses a topical curing solution that contains the diffusive transport modifier(s) for delivery into the concrete. While the penetration depth of the admixture may be limited by the permeation properties, sorptivity and permeability, of the concrete, this delivery route may offer an advantage over admixing directly into the wet concrete mixture when the viscosity modifier has significant detrimental influences on the cement hydration reactions (such as retarding effects) or the fresh concrete properties, such as air entrainment or detrainment.

[0031] In yet another aspect of the present invention, porous lightweight aggregates (LWA) are saturated with a concentrated solution of the diffusive transport modifier(s) prior to their incorporation into a wet concrete mixture. As the cement hydrates, this internal curing solution may be drawn from the larger pores in the LWA into the smaller pores in the hydrating cement paste matrix, uniformly distributing the diffusive transport modifier(s) throughout the pore solution in the concrete.

EXAMPLES

Example 1

[0032] Potential diffusive transport modifiers were initially screened. Size (i.e. molecular weight) and effects on the viscosity of water as well as effects on electrical conductivity of an ion solution were then evaluated for selection for further testing to determine the effectiveness as a diffusive transport modifier. The results of this initial screening are shown in Table 1.

[0033] Solution bulk viscosities were measured using a Cannon-Fenske Routine viscometer in which the time needed for the solution to flow between two marker lines was measured; all viscosity measurements were estimated to less than 1% uncertainty. Solutions having various concentrations were prepared, as necessary, to achieve an increase in solution viscosity ranging from about 1.4× to about 3.3× that of distilled water (i.e. $\eta_{water}/\eta_{solution} \approx 0.30\text{-}0.71$).

[0034] The electrical conductivity of the aqueous solutions was determined using a conductivity cell having a diameter of 25 mm and an electrode separation of 150 mm (the cell constant was $0.31455 \pm 0.00010\ mm^{-1}$). The cell was calibrated using standard potassium chloride (KCl) solutions, and all conductivity values were estimated to less than 1% uncertainty. KCl was selected to serve as a chloride "invader" or deleterious species to the aqueous diffusive modified solutions, acting as a surrogate cementitious pore solution. These diffusive modifier solutions were first prepared and then KCl was added to the solutions at a concentration of 0.100 mol/kg. The resulting bulk electrical conductivities were compared to those of KCl solutions in distilled water at the same concentration.